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ON THE OUTCROP

Dinosaur Tracks and Trackways in the Escalante Member of the Entrada Formation (Middle Jurassic), Twentymile Wash, Grand Staircase-Escalante National Monument, Utah

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Location

The trackway site is located in the Straight Cliffs area of the Grand Staircase-Escalante National Monument (fig. 1). The locality can be reached by 2WD vehicles with high clearance, but be aware that the Collet Top Road can flood and become impassable. It is recommended you check with the Escalante Interagency Visitor Center (755 West Main, Escalante, UT, 435-826-5499) prior to traveling to the site to get the latest information on road conditions and weather (rains storms are common in this part of Utah in the late afternoon during the summer months). Drive east out of Escalante, Utah on UT 12 to Hole-in-the-Rock Road, Grand Staircase-Escalante National Monument, approximately 5 miles [8.04 km] east of Escalante, UT. Turn south on Hole-in-the-Rock Road. Initially, you will be crossing the Carmel Formation, which can be slick when wet but you will drive up onto the Entrada Formation and the road gets better. Approximately 12 miles [19.3 km] after turning off UT 12 you will see a turn off to Devil's Garden (Devil's Garden Road). Continue approximately 2.1 miles [3.37 km] to 'Collet Top' Road and turn right. Travel southwest for approximately 2.3 miles [3.7 km] to junction of Right and Left Collet Canyon Road and take the right fork (Right Collet Canyon Road). In approximately 0.3 miles [0.48 km] the road will swing left; continue another 0.2 miles [0.32 km] to a small turnout. You should be facing the Escalante Member of the Entrada Sandstone (fig.

2). Outcrop is located at GPS coordinates N37.55156° and W111.42375° and an elevation of approximately 5,338 ft [1,620 m].

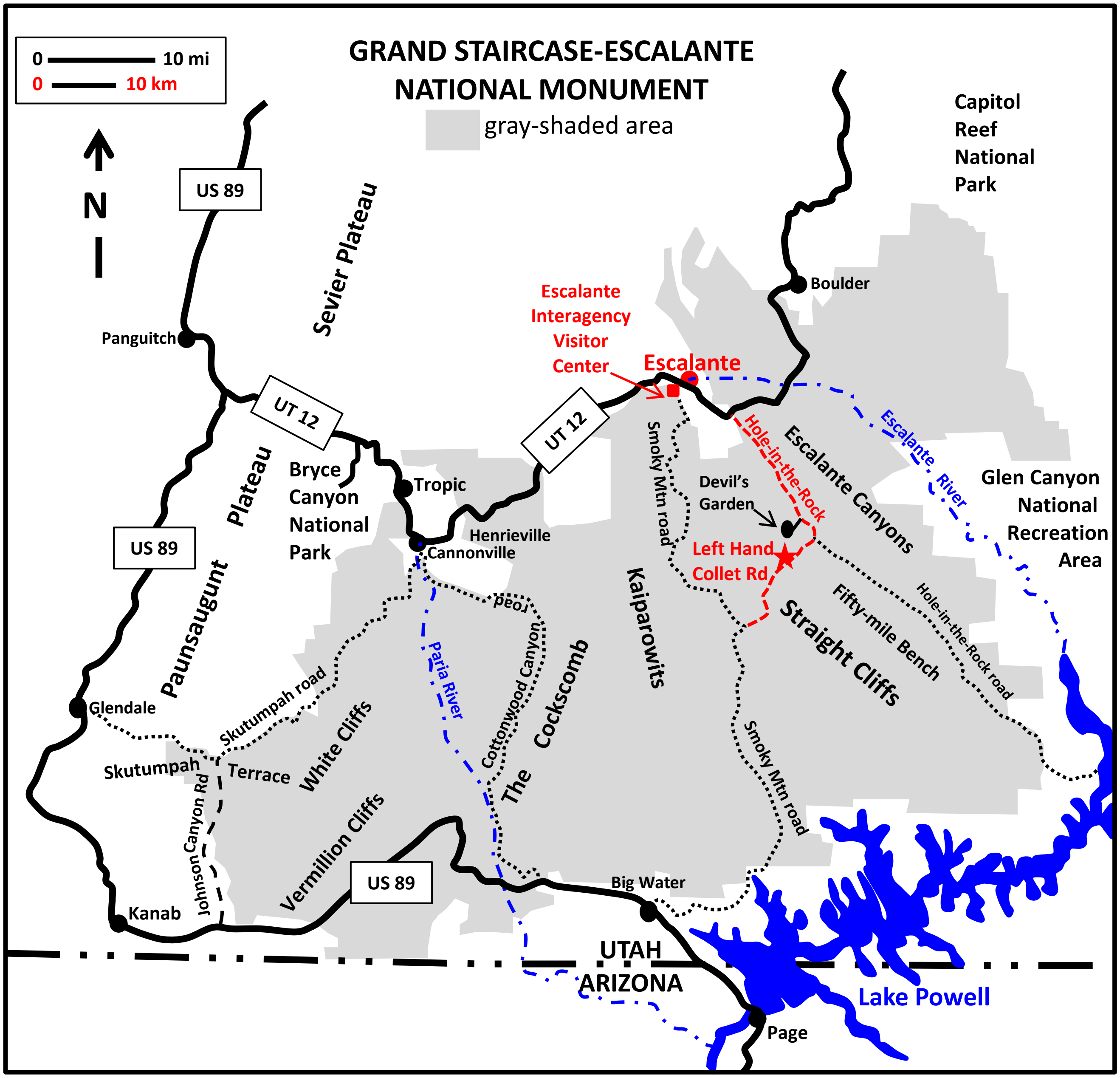


Figure 1. Generalized map for the Grand Staircase-Escalante National Monument (GS-ENM), with roads and physiographic regions within the park. Note the location of the Escalante Interagency Visitor Center (in red) for checking on road conditions. Directions to outcrop are based on mileages from Escalante, UT (in red) along the Hole-in-the-Rock Road and Left Hand Collet Road (in red).

Figure 2. View to the north at the outcrop of the Escalante Member of the Entrada Formation containing dinosaur trackways. The majority of the tracks are located on the east-west trending, upper-most bench (red arrows).

Significance of the Site

Dinosaur tracks are relatively abundant in the Mesozoic strata of the western U.S. (Lockley and Hunt, 1995). Lockley *et al.* (1998) reported more than thirty-five track sites in strata of Permian through Late Jurassic age in the Glen Canyon National Recreation area (GCNRA). Immediately to the west of the GCNRA, in the Grand Staircase-Escalante National Monument (GS-ENM), Hamblin (1998) reported vertebrate footprints in the Moenkopi, Chinle, Wingate, Moenave, Kayenta, Navajo and Straight Cliffs Formation and Foster *et al.* (2000) reported on the first tracks found in Entrada Formation (fig. 3). This "On the Outcrop" report focuses on the track site reported by Foster *et al.* (2000) and Milán and Loope (2007), which is part of the Entrada-Summerville transition zone in Utah (Milán and Loope, 2007). The transition zone can be traced in various outcrops for about 1000 km^2 as part of the Moab Megatracksite (Lockley and Hunt, 1995; Lockley, 1997).

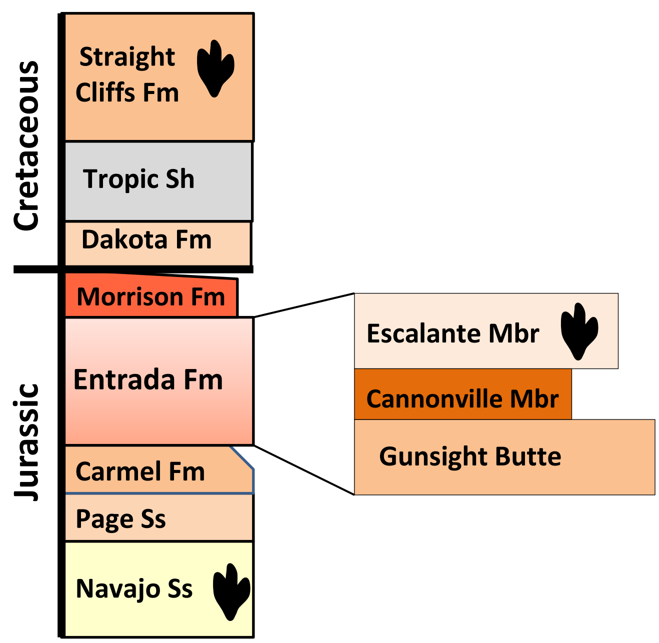


Figure 3. Generalized stratigraphic column of late Jurassic and early Cretaceous strata in the Grand Staircase-Escalante National Monument. Dinosaur tracks are found in the Escalante Member of the Entrada Formation, as well as in the Straight Cliffs Formation and Navajo Sandstone.

Several hundred dinosaur footprints are preserved in the upper portion of the Escalante Member of the Entrada Formation. Although dinosaur tracks may be found along several of the exposed benches, the main track-bearing horizon is the upper bench, which trends east-west for approximately 400 meters (fig. 4). Some tracks can be found on the lower bench surface.

Figure 4. View along the east-west trending upper bench surface containing the majority of tracks and Trackways and the lower bench, which contains a few tracks and trackways.

Entrada Dinosaur Tracks

The dinosaur tracks do not show distinctive relief (molds/casts), and therefore are not initially visible. Erosion of the sandstone has exposed the tracks in a random variety of cuts at different angles through actual tracks and horizons of undertracks. The tracks appear as darker gray areas (sand infillings) surrounded by alternating light and dark laminations of concentric sand deformation (fig. 5). Two ichnogenera have been identified by Foster *et al.* (2000). Foster *et al.* (2000) also suggest a third, but smaller, ichnogenera maybe present - *?Therangopodus.*

Ichnogenera *?Megalosauripus* is a theropod (biped) with large (34-45 cm in length), three-toed, bird-like tracks (fig. 6), and classification is based upon similar, large theropod tracks found in the Moab Utah Megatracksite and assigned to ichnogenera *?Megalosauripus* by Lessertiseur (1955). Based on measurements of one theropod trackway, Foster *et al.* (2000, p. 171) suggest a walking speed of 5.3 km/hr.

Ichnogenera *?Brontopodus* is a sauropod (quadruped) with large, tracks (fig. 7), and classification is based on similarity to sauropod tracks from the early Cretaceous Glen Rose Limestone (Texas) by Farlow *et al.* (1989). The trackway consists of six pes tracks and the final four have associated manus tracks. The trackway is oriented toward the south at approximately 170° and has what appears to be a rare, mid-line tail drag impression. *?Brontopodus* pes tracks are approximately 60-65 cm long and 20-22 cm wide.

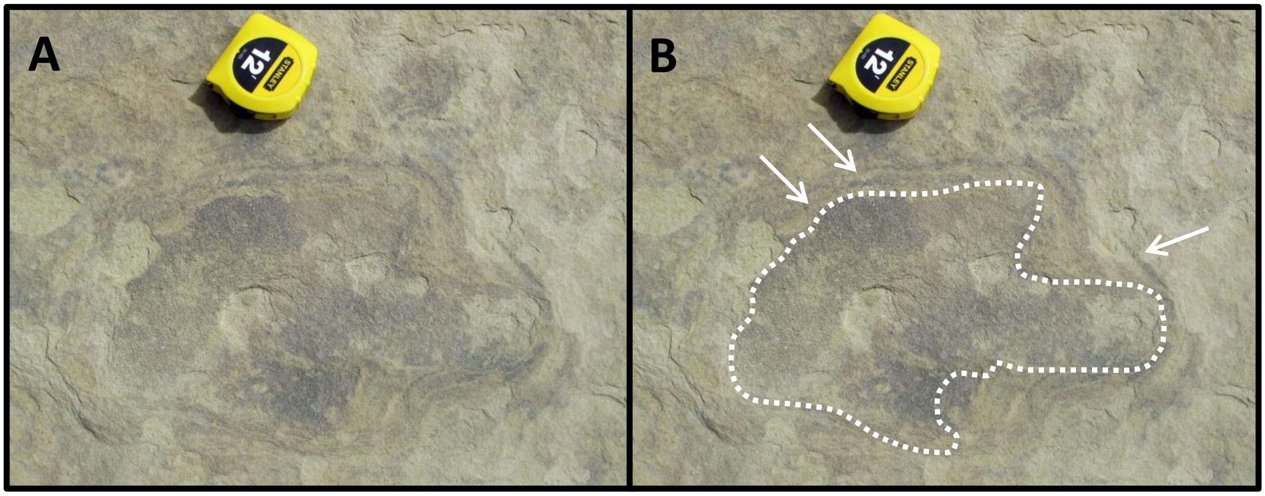
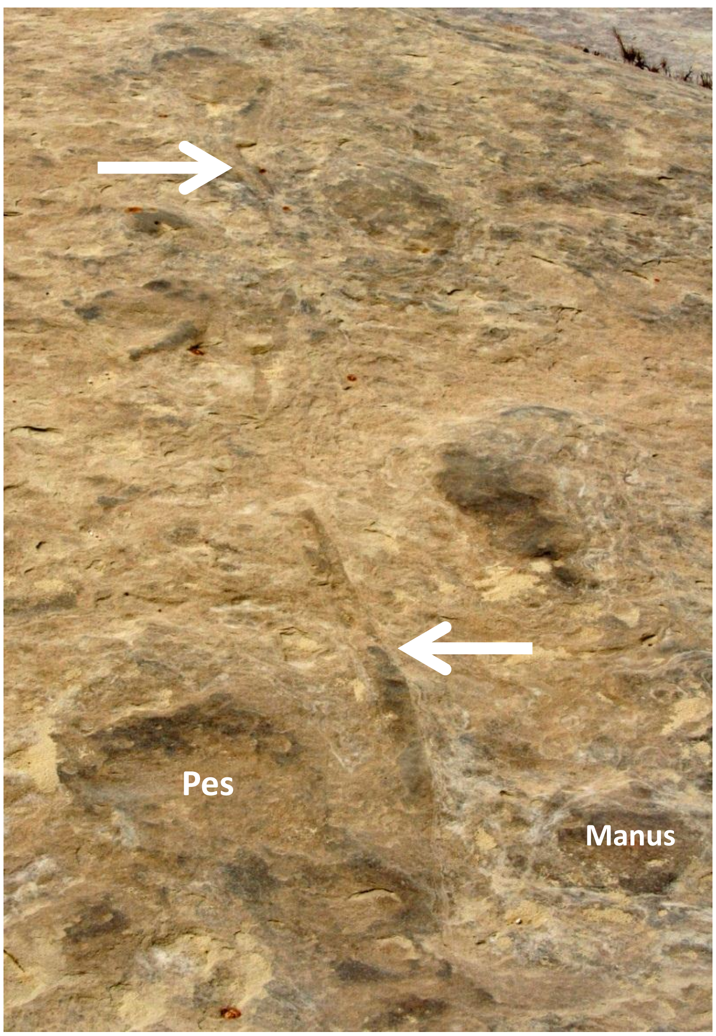


Figure 5. A illustrates the typical appearance of tracks on the outcrop. **B** is the same photo with a rough outline of the dinosaur track added. White arrows point to infillings typically observed around the track



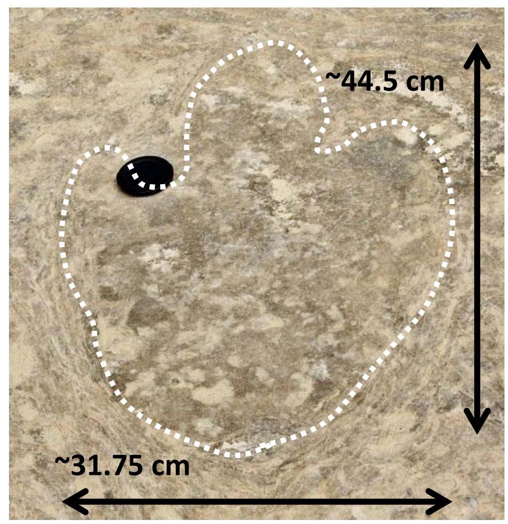


Figure 6 (above)**.** Example of a large track assigned to the ichnogenera *?Megalosauripus* (outlined). Note the concentric darker deformation lines around the margins of the dotted track outline.

Figure 7 (left). *?Brontopodus* sauropod trackway. Arrows indicate tail trace. Pes and manus tracks are indicated.

One *?Megalosauripus* trackway trends approximately 295° for a distance of nearly 130 feet [39.6 m]. Thirty-seven distinct tracks were recognized in this single trackway (fig. 8). At approximately 110 feet [33.5 m] along the length, the trackway was cut by a second trackway.

Figure 8. A portion of the 130-foot long trackway with individual tracks wetted to illustrate the stride pattern. The true tracks have been eroded away and only the erosional cut through the concentric undertracks reveals the presence of the trackway.

Depositional Environment of Entrada

As the Sundance Sea withdrew northward, a vast desert (erg) developed. Large-scale, cross-bedded sands of the Entrada Formation were deposited over tidal flat mudstones (fig. 9).

The Entrada Formation is subdivided into the lower Gunsight Butte Member, middle Cannonville Member, and the upper Escalante Member (fig. 10). The Escalante Member is only present in the northern half of the GS-ENM (Doelling *et al.,* 2000).

The Gunsight Butte Member weathers to form cliffs and rounded, 'slickrim' outcrops. In the area around the dinosaur tracksite, the Gunsight Butte Member weathers to light, yellowish-brown to yellowish-orange color. Along the Hole-in-the-Rock Road area the member is 200-450 feet thick (Doelling *et al.*, 2000). The Gunsight Butte Member contains very fine- to fine-grained, silty, subrounded to round quartz and exhibits large-scale eolian cross-bedding.

In the Hole-in-the-Rock area, the Cannonville Member appears a deep-reddish brown in outcrop and is easily distinguished from the Gunsight Butte and Escalante Members. Although thicknesses range from 200 to 400 feet, in the area of the dinosaur track site, this member is typically only 60-80 feet in thickness. The Cannonville Member is an interbedded, very fine grained sandstone, silty sandstone, and siltstone.

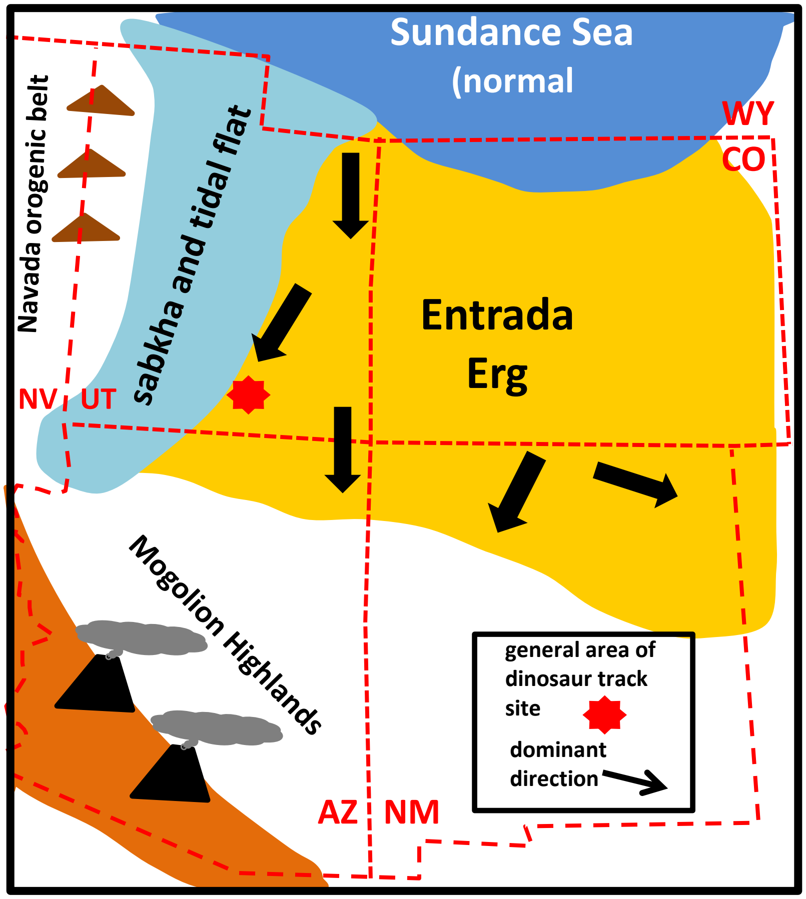


Figure 9. Paleogeography of the Colorado Plateau during deposition of the Middle Jurassic Entrada Formation. Adopted from Fillmore (2000).

Figure 10. Outcrop of the Entrada Formation at the Devil's Garden just north of the track site. The Gunsight Butte, Cannonville, and Escalante Members have been delineated.

The Escalante Member forms rounded, 'slickrim', yellowish-gray to grayish-white outcrops. Cavities along the planes of cross-bedding are relatively common (figs. 11 & 12), and the origin of these cavities is debated. According to Davidson (1967), the cavities are dissolution features, while Doelling *et al.* (2000) believe that air 'bubbles' lodged between sand grains prevented cementation by the movement of groundwater through the sands. When erosion exposed the 'bubbles', the sand simply fell out, leaving a cavity behind. Some of the cavities are quite large (fig. 12).

Figure 11. Cavities forming along planes of cross-bedding in the Escalante Member of the Entrada Formation. Photo was taken at the track site outcrop, as was figure 12 (below).

Figure 12. Exposure of larger cavities, which cross-cut the cross-bedding planes.

The Escalante Member is a calcareous-cemented, fine-grained quartz sandstone. Sands accumulated above a shallow water table (Loope and Simpson, 1992) and the dinosaur tracks likely formed during moist periods (Loope and Rowe, 2003). When exposed, the lower half of the member is very friable and forms vegetated, sandy slopes, while the upper portion forms rounded to cliffy bare-rock outcrops. In the area of Fiftymile Bench, the Escalante Member of the Entrada Formation is unconformably overlain by the Tidwll Member of the Morrison Formation.

It is clear that the Escalante Member of the Entrada Formation was deposited in an area characterized by eolian dunes and tidal flats near an inland sea. Lockley and Conrad (1989) report sauropod tracks associated with clastic and carbonate lacustrine deposition systems, but only in carbonate shorelines of delta/coastal plain depositional systems. The presence of sauropod tracks in the Escalante Member of the Entrada Formation would certainly indicate sauropods had transited the area. Although we found no reference to plant fossils in the Entrada Formation, conifers were common during the Jurassic. Abbink *et al.* (2001) report several species of conifers as characterizing the vegetation of the coastal plains in Late Jurassic. If the same were true of the Middle Jurassic then it would suggest enough vegetation would be present in the eolian dunes and tidal flats of Sundance Sea coastal plain to sustain sauropods, which would, in turn, sustain theropods. The abundance of theropod tracks in the Entrada Formation would suggest that sauropods would also have to be fairly abundant, but that sauropod tracks and trackways were less commonly preserved. Investigating this hypothesis could be a fruitful area of future research.

Protection of Trackway Site

This tracksite is located within the Grand Staircase-Escalante National Monument and the archeological, biological, geological, and paleontological resources are protected by law. Collection of the tracks at this site is prohibited. In addition, please do not sweep sand off the tracks, make rubbings or castings of the tracks, and do not carve, paint, or otherwise deface or alter the tracks. Photograph the tracks and leave them for others to study and enjoy.

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